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DETERMINATION OF PHASE TRANSFORMATION TEMPERATURES OF TITANIUM-NICKEL USING DIFFERENTIAL THERMAL ANALYSIS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Some of the more popular methods used to determine phase transformations in metals are x-ray, dilatometry, and electrical resistivity. Data reported for the TiNi alloy using Differential Thermal Analysis (DTA) is quite sparse and it appears that little effort has been made to correlate these results with x-ray, dilatometry, or resistivity data. The purpose of this investigation was to determine the M_s and A_s temperatures for several alloys having compositions

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20. Abstract (Cont'd)

near 50 atomic percent titanium. The DTA method was used. The results are compared with those reported by several investigators that used different techniques. The DTA data obtained shows excellent agreement with Kornilov's A_s temperatures,[1] as a function of composition, obtained by dilatometry. A small variation was found between the results of this study and Wasilewski's x-ray data,[2] and Hanlon's resistivity measurements[3] for the M_s temperatures. It is concluded from this investigation that DTA analysis is a credible method for determining phase transformation temperatures for the TiNi material.

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INTRODUCTION

Many different methods have been used to determine phase transformation temperatures in metals. Table I lists some of the more popular ones - though not necessarily in their order of importance. References cited in the tables are examples and not meant to be all inclusive. For the most part, the investigators listed studied the titanium-nickel (TiNi) system, but there are some exceptions. Many additional references are listed in references 10 and 11. The selected references cited in the text are not in the same order as those listed on the reference page.

Although there have been some efforts using Differential Thermal Analysis,[1,4,12] the data is quite sparse and it appears that little effort has been made to correlate the results with other techniques for the TiNi system. The objective of the study was to determine transformation temperatures using Differential Thermal Analysis (DTA) and then compare these results with those obtained by x-ray, dilatometry, and electrical resistivity methods.

References are listed at the end of this report.

TABLE I. VARIOUS METHODS USED TO STUDY PHASE TRANSFORMATIONS

Author	Method	Ref. No.
R.J. Wasilewski et al	X-Ray	1
I.I. Kornilov et al	Dilatometry	2
W.B. Cross et al	Elect. Resistivity	3
H.U. Schuerch	Diff. Thermal Anal.	4
G.R. Speich et al	Acoustic Emission	5
R.R. Hasiguti et al	Internal Friction	6
N.G. Pace et al	Ultrasonic	7
C.M. Wayman	Metallographic Techs.	8
K.H. Eckelmeyer	Strain-Temp Techs.	9

EXPERIMENTAL MATERIALS USED

Three different heats of the material were supplied by Titanium Metals Corp. and some additional material by Reactive Metals, Inc. in the form of one-half inch diameter rods. These alloys had compositions in the range of 49 to 51 atomic percent titanium. Thin slices 1/16 inch thick were cut from the rods using a low speed metallurgical saw. Small pie-shaped pieces weighing approximately 15 to 25 milligrams were then cut out of the disks so that they would fit into the pan of the Differential Thermal Analyzer.

Some material was kindly supplied by Goodyear Aerospace Corp. in the form of 100 mil diameter wire. This was cut into thin disks and tested in the DTA without further cutting.

The equipment used was a Dupont 990 Differential Thermal Analyzer. The heating and cooling rates were 10°C per minute. Upon cooling, an exothermal peak was obtained which was indicative of the M_s temperature. The M_s temperature is defined as the temperature at which the parent phase starts to transform to Martensite. On subsequent heating an endothermic peak was obtained and gave the A_s temperature. The A_s temperature is defined as the temperature at which the martensite starts to transform back to the parent phase. For specimens having rather low M_s temperatures, a cold cell filled with liquid N_2 was used to provide adequate cooling. Figure 1 is a copy of an actual trace showing these peaks.

RESULTS AND DISCUSSION

Figure 2 is a replot of an M_s transformation curve using data obtained by Kornilov et al[2] by the method of dilatometry. Here I have taken the liberty to plot the transformation temperatures vs. atomic percent titanium rather than atomic percent nickel as done by Kornilov. For brevity, Figure 2 also contains a plot of x-ray data from Table I of reference 1 as well as a replot of resistivity data obtained from Figure 7 by Hanlon et al.[13] In this case I have used °C on the ordinate rather than °K used by the authors. In Figure 3, M_s data obtained in the present study by the DTA method is presented. Figure 4 shows some miscellaneous DTA data superimposed on the line from Figure 3 along with some additional resistivity data by Cross et al.[3] With the exception of the one data point by Wang et al,[12] the data agrees quite well with that obtained in the present study. Figure 5 is a summary plot showing a superposition of the results for the M_s temperatures from Figures 2 to 4.

Results from the present study are about as far to the right of the Wasilewski and Hanlon lines as the Kornilov results are to the left. The overall difference in the results in the temperature range from -60° to +60° is less than one percent on the composition axis. An average for the four studies would be close to the Wasilewski-Hanlon curves. The very striking thing about these results is how sensitive the transition temperature is to composition.

Figure 6 shows a replot of Kornilov's data for the A_s temperatures. Also included are some data from Figure 3 of Eckelmeyer's report.[9] Eckelmeyer obtained this data by straining the specimens approximately four percent, unloading, heating, and then observing the temperature at which the specimen starts to contract (revert back) to its original length. Unfortunately, for this comparison, most of the data is located in the composition range where the transformation temperature is relatively insensitive to temperature. Figure 7 is a plot of data obtained in the present study by the DTA method. Figure 8 is a plot of some miscellaneous DTA data as well as some resistivity data superimposed on the results from Figure 7. In this case the scatter seems to be a little larger than in the plot for the M_s temperatures. Finally, Figure 9 is a superposition of the results from Figures 6 and 7 showing excellent agreement for the three separate studies.

Results from this study indicate that DTA can be a viable method for determining phase transformation temperatures in the TiNi system. If carefully done, it can provide information less expensively than that obtained by using highly sophisticated equipment such as x-ray. It could be a helpful ancillary tool in stress-assisted martensitic, shape memory transformation studies.

CONCLUSIONS

1. Based on the excellent agreement of the data from this study with that previously obtained by other methods, it can be concluded that DTA is a credible method for determining phase transformation temperatures in the TiNi system.

2. The sensitivity of the M_s and A_s temperatures with composition which is of the order of 100°C for one atomic percent increase in titanium indicates the potential problems that can arise in seeking repeatability of behavior for TiNi material.

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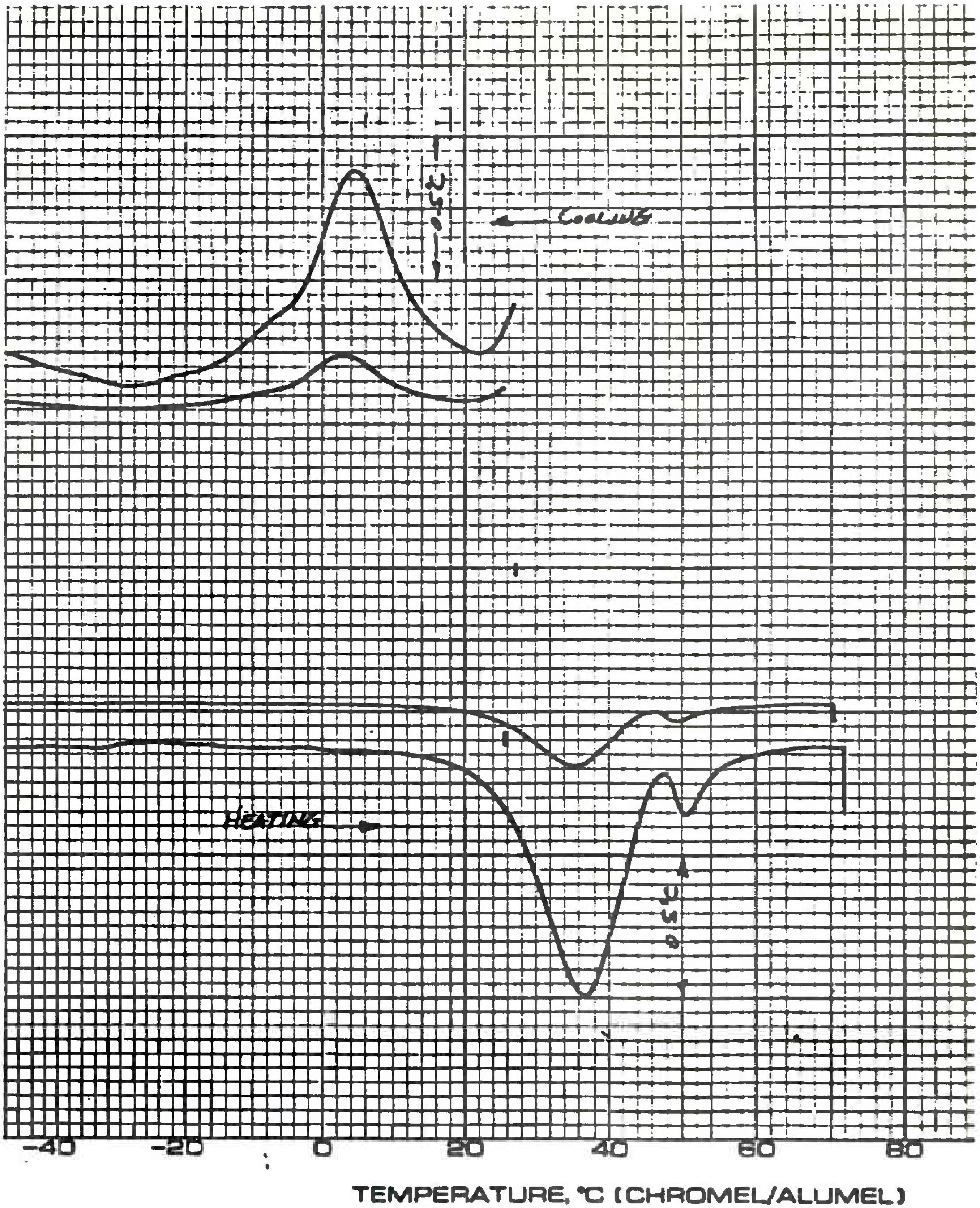


Fig 1. Change in Differential Temperature vs Temperature. Traces were obtained using a Differential Thermal Analyzer. The top trace shows an exothermic peak on cooling and the bottom trace shows an endothermic peak on subsequent heating. The smaller peaks are the same data on another pen with a suppressed vertical scale.

Figure 2

M_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM

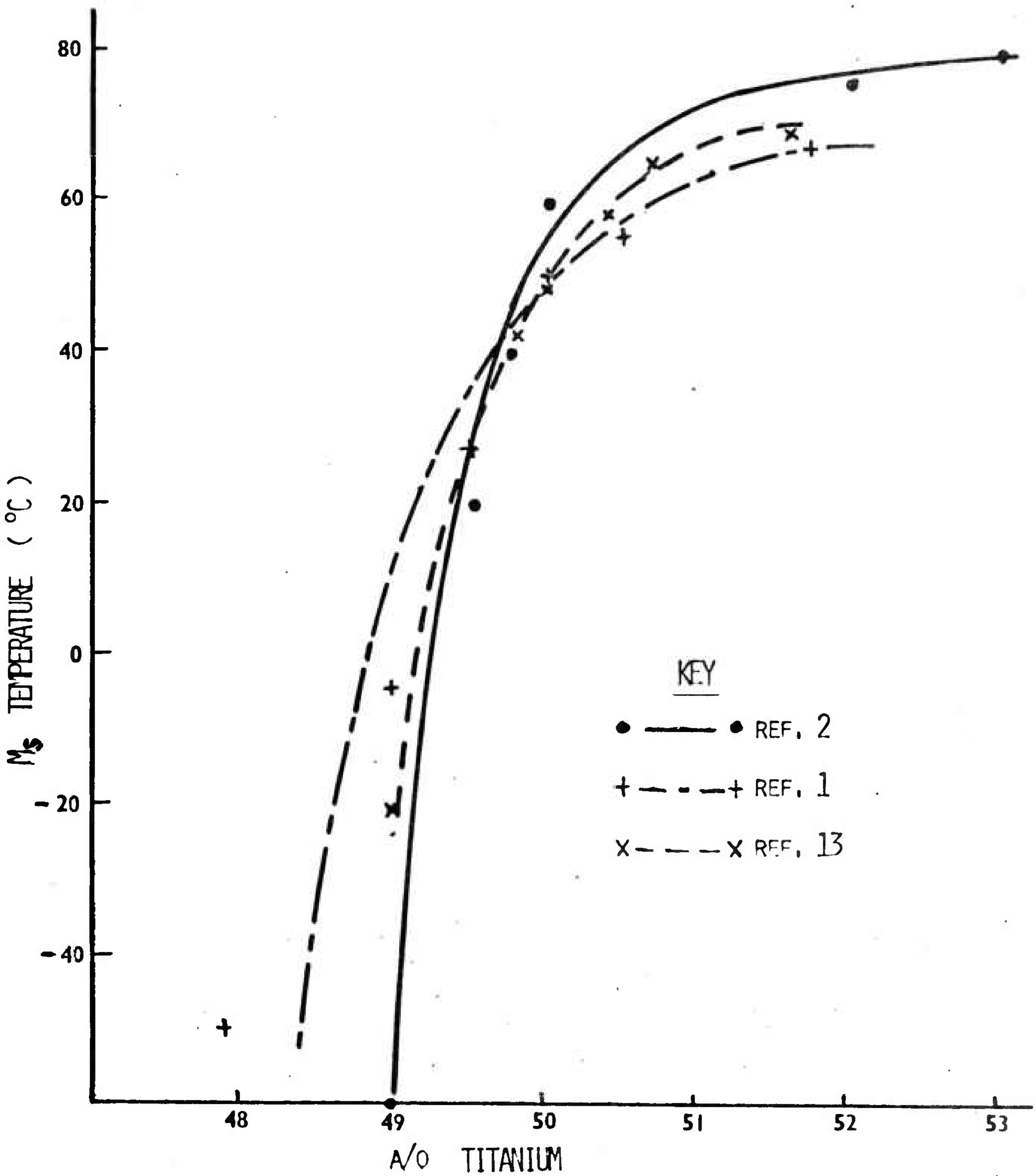


Figure 3

M_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM

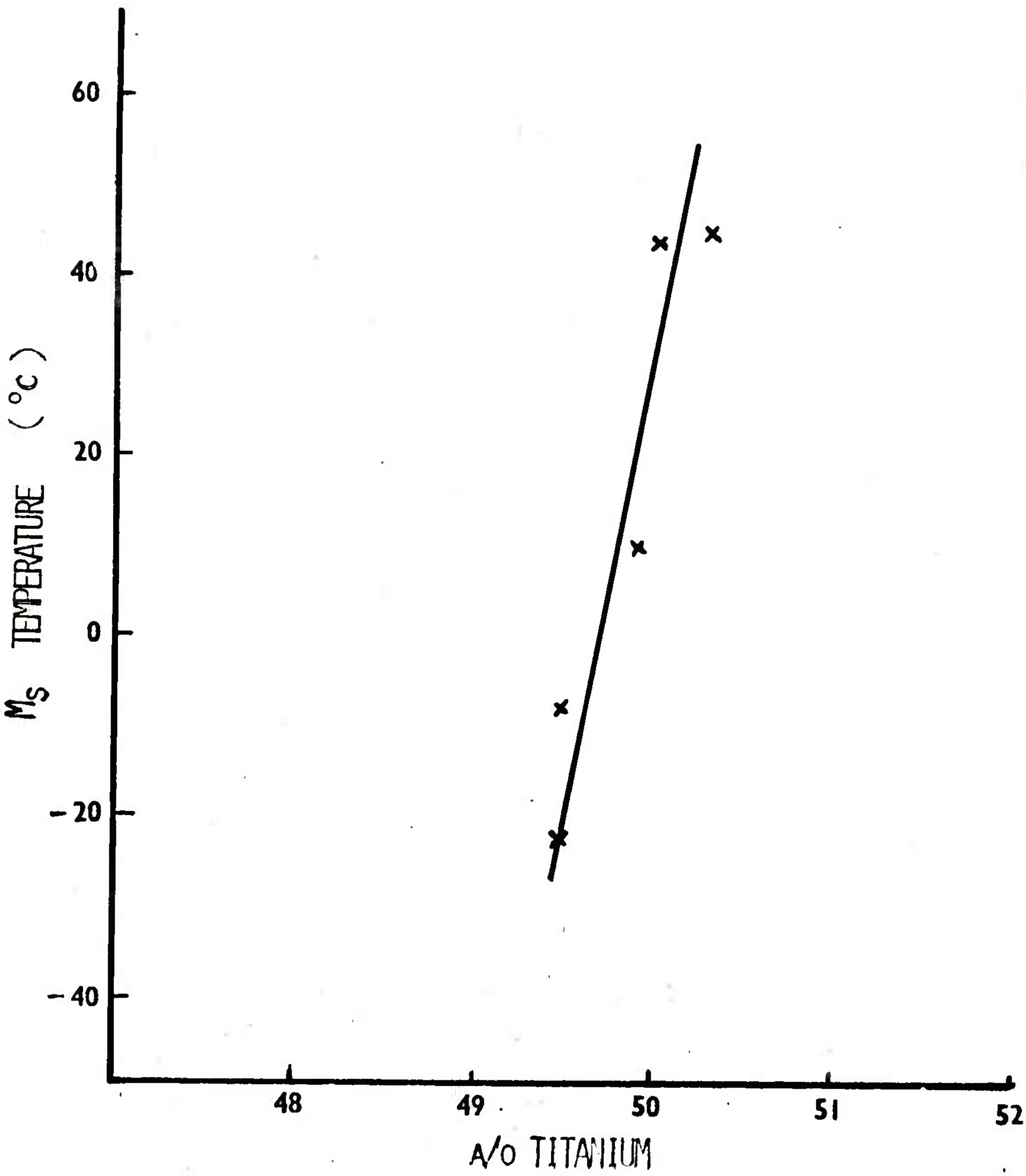


Figure 4

M_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM

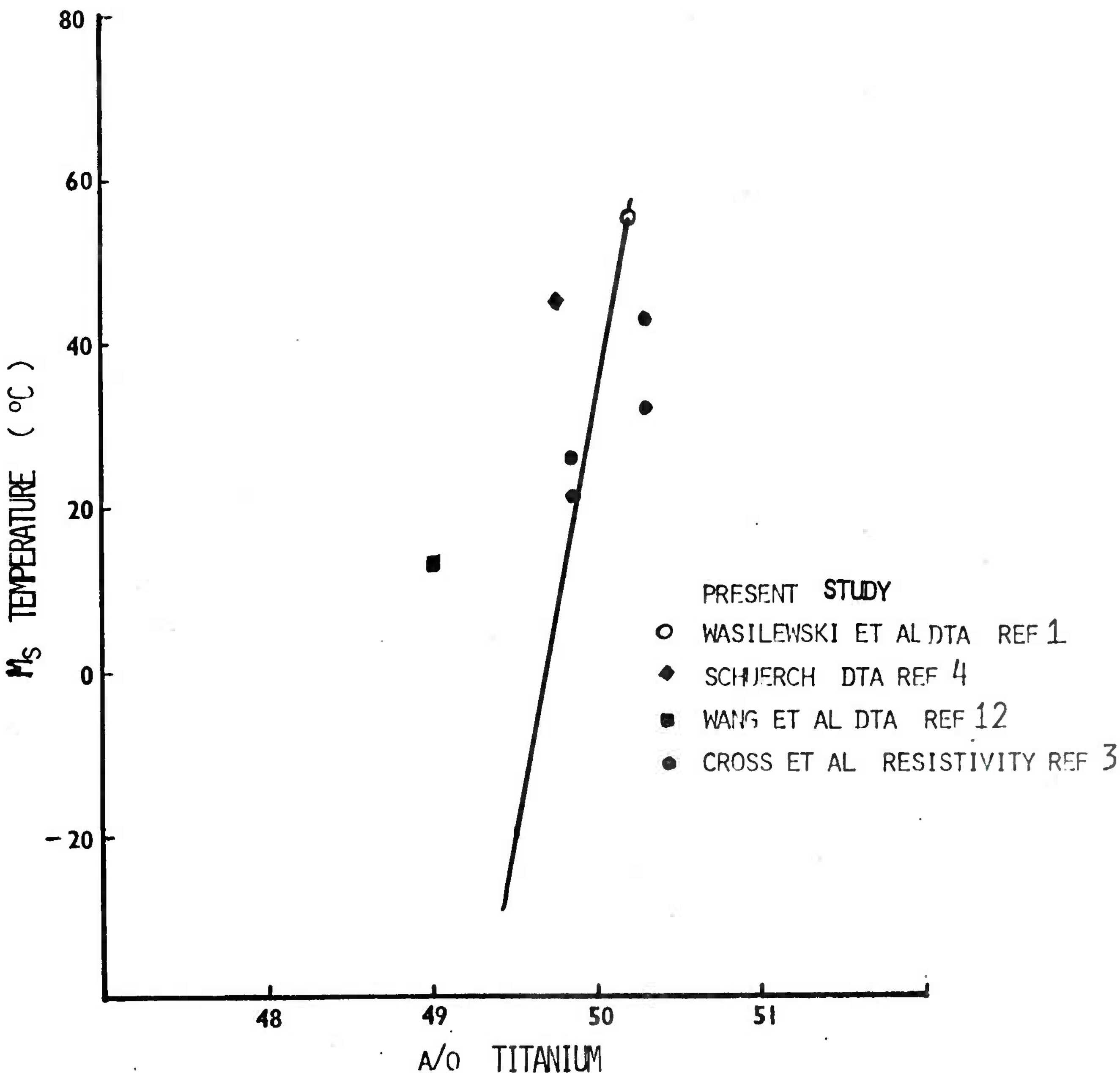


Figure 5

M_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM

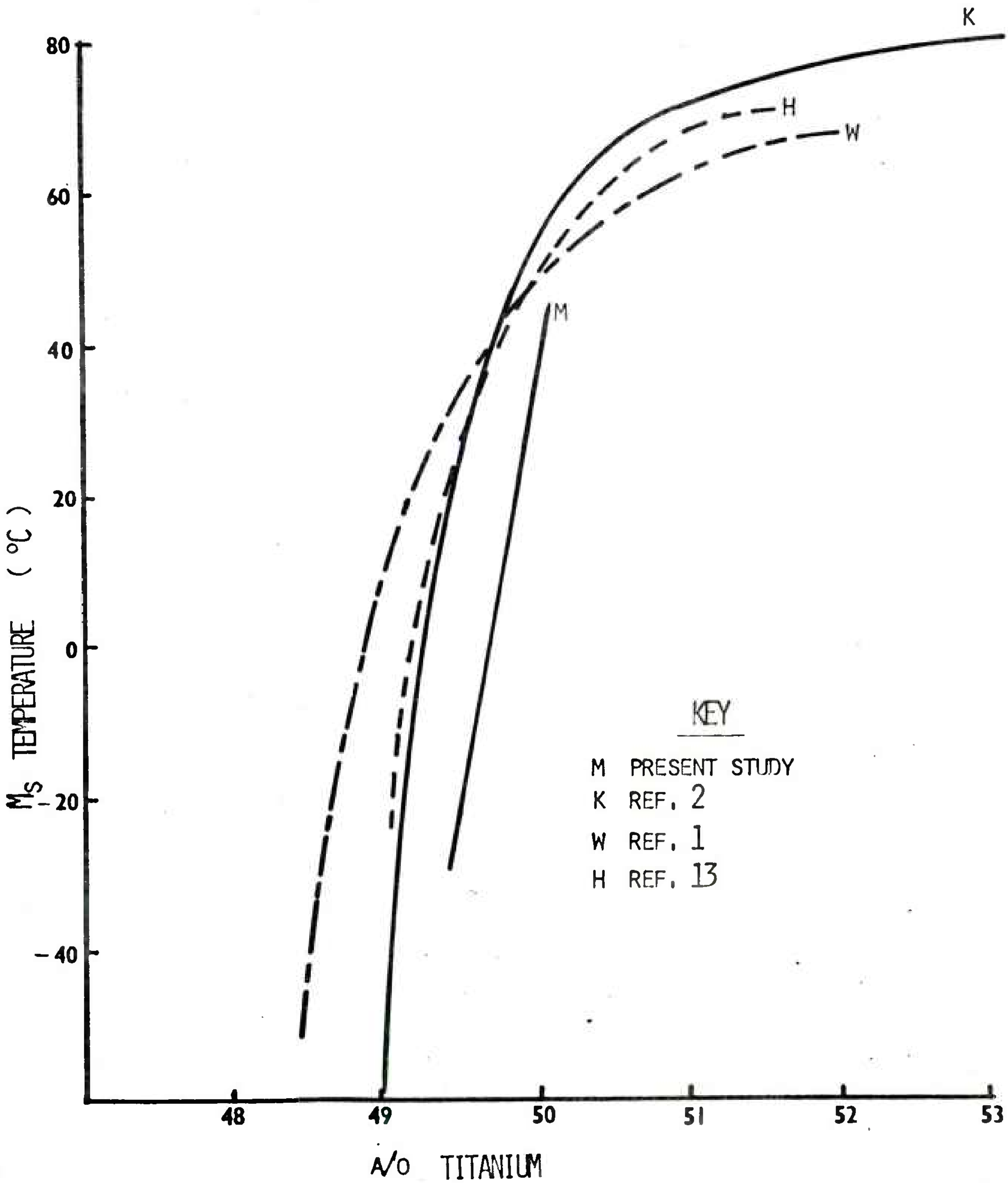
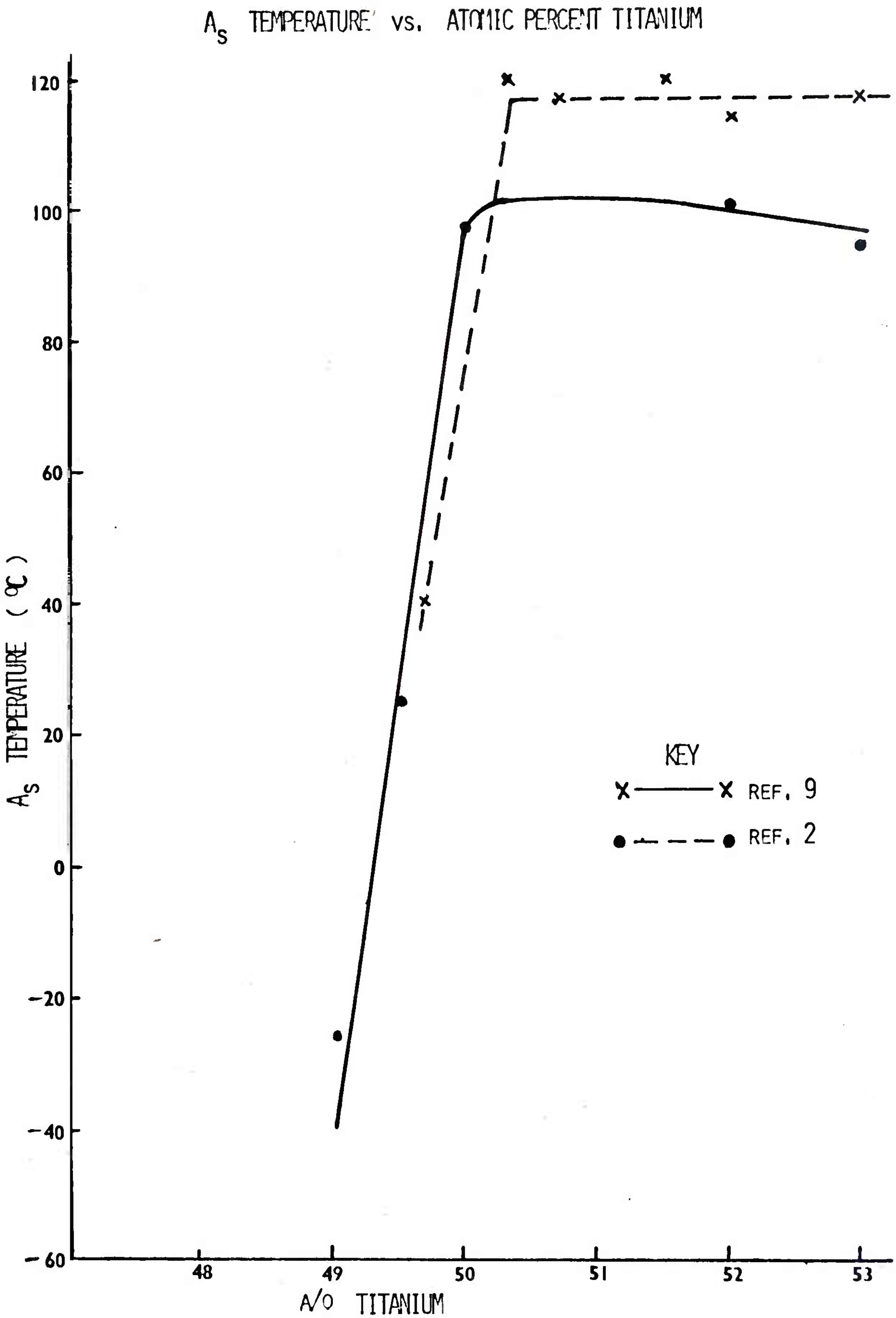


Figure 6



A_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM
120
100
80
60
40
20
0
-20
-40
-60
A_S TEMPERATURE (°C)
48
49
50
51
52
53
A/O TITANIUM
KEY
REF. 9
REF. 2

Figure 7

A_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM

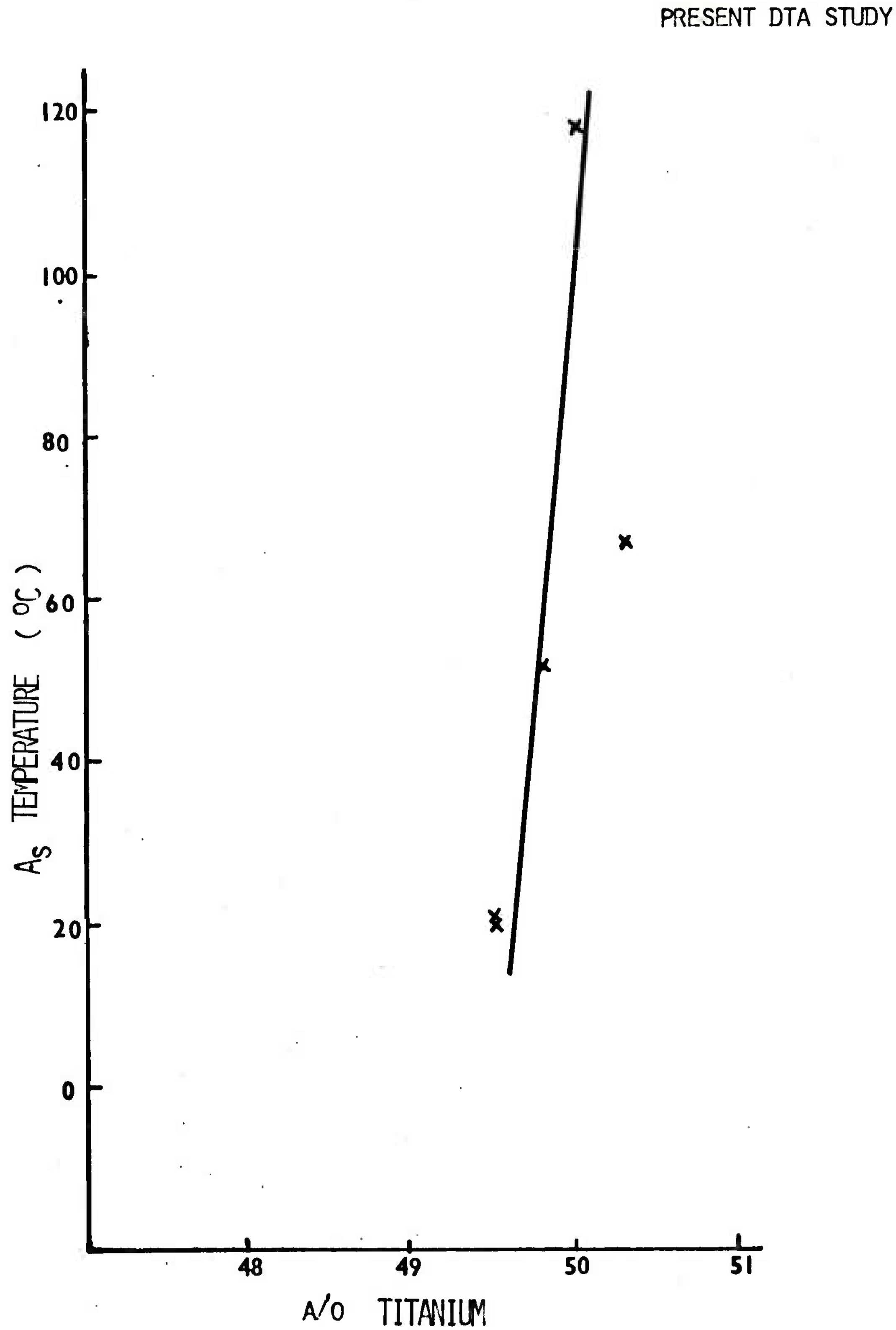


Figure 8

A_s TEMPERATURE vs. ATOMIC PERCENT TITANIUM

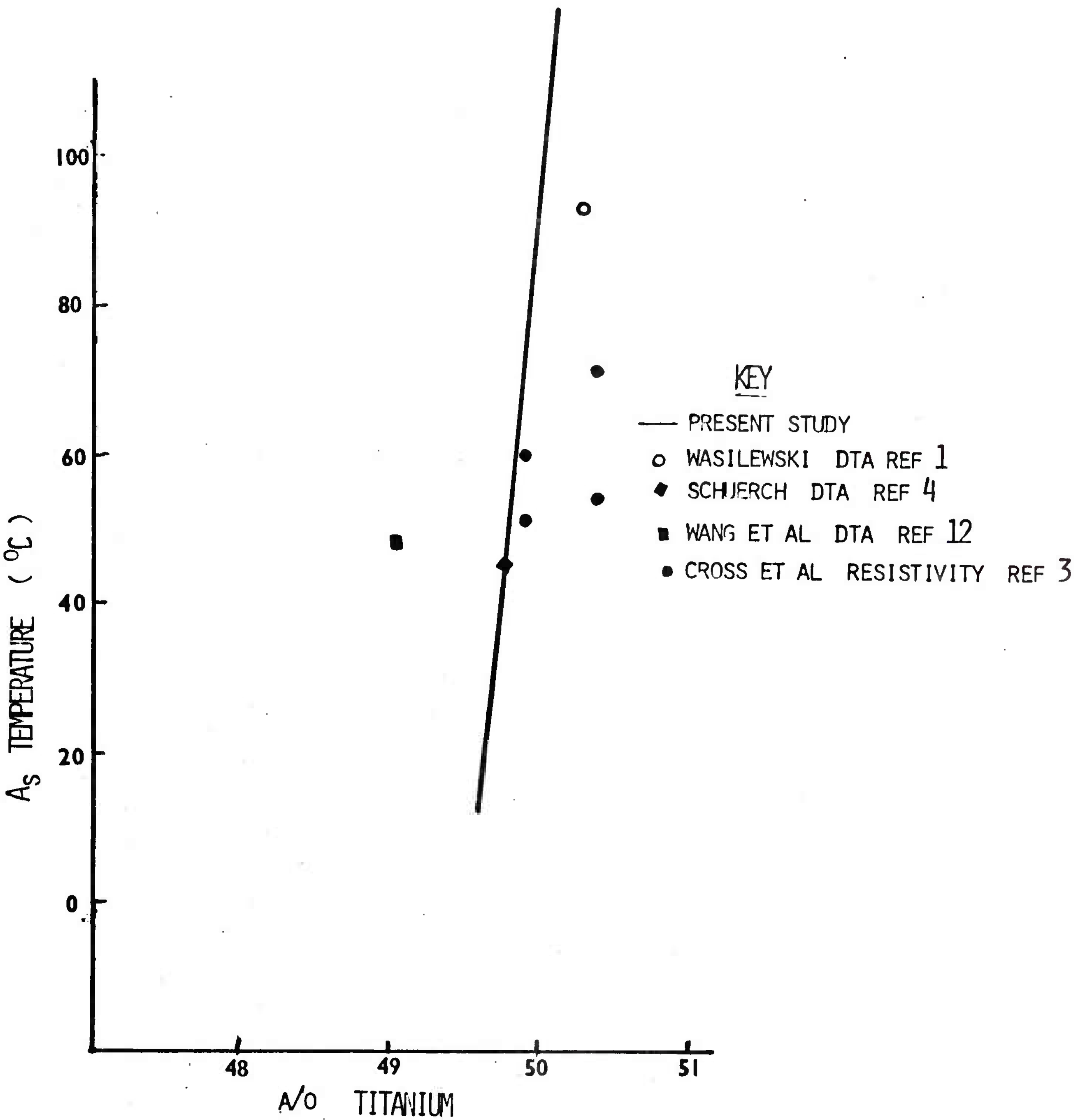
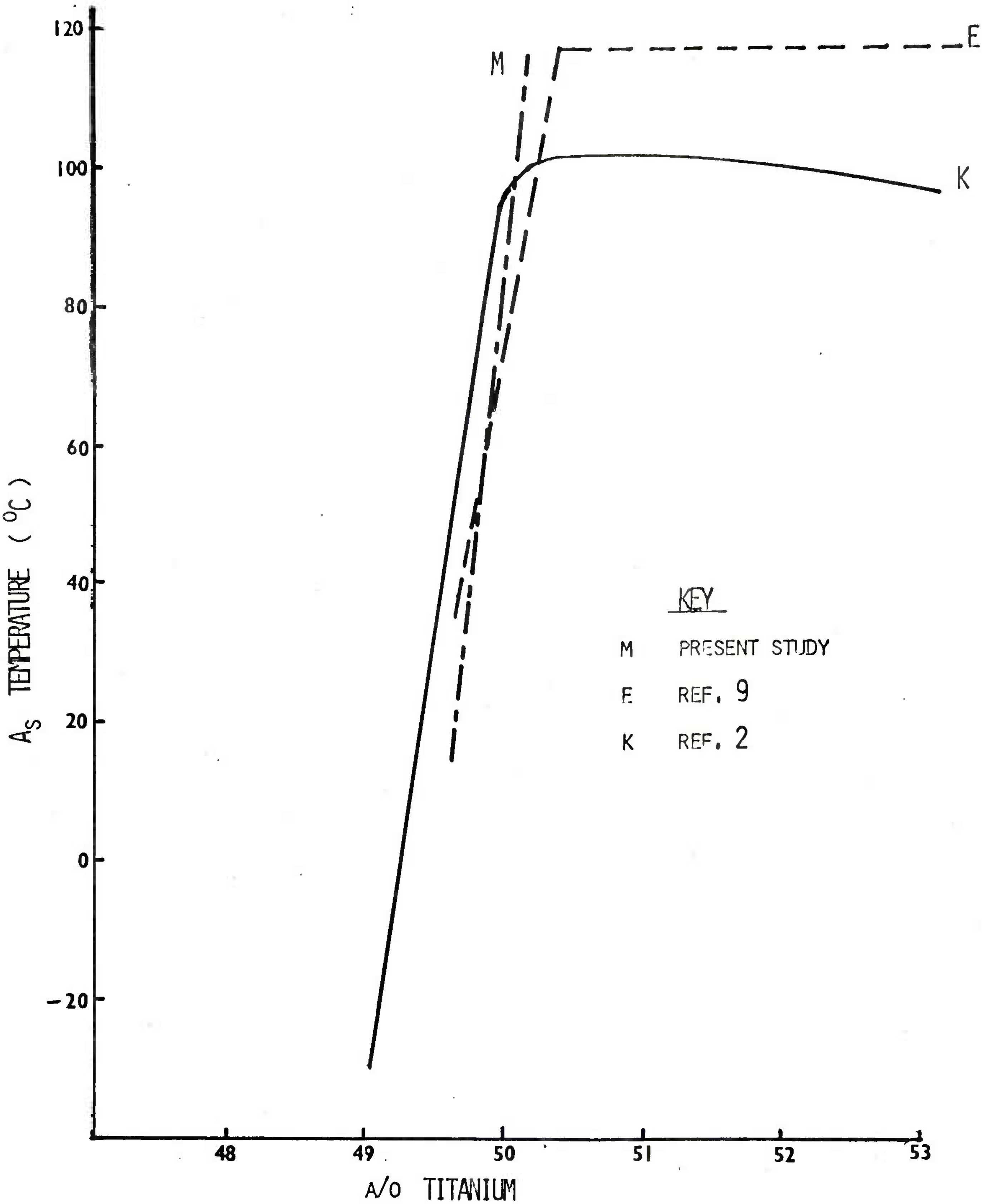


Figure 9

A_S TEMPERATURE vs. ATOMIC PERCENT TITANIUM



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